FIRST DINOSAUR BONES FROM WESTERN AUSTRALIA.

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ABSTRACT

A proximal end of a reptilian right humerus from the Late Maastrichtian Miria Formation, Carnarvon Basin, is identified as possibly belonging to a theropod dinosaur, based on the shape of the deltopectoral crest and the slender shaft. A small caudal vertebra from the Middle Jurassic Colalura Sandstone, near Geraldton, may belong to the Dinosauria on the basis of its overall similarity with caudal vertebrae of sauropod dinosaurs. These are the first recorded bones of dinosaurs from Western Australia.

KEYWORDS: Cretaceous, Jurassic, dinosaurs, Western Australia, Miria Formation, Colalura Sandstone.

INTRODUCTION

Dinosaurs have been known from Western Australia since the mid 20th century from footprints in the Lower Cretaceous Broome Sandstone (Glauert 1952, Colbert and Merrilees 1967). Despite numerous finds of Mesozoic reptile bones from throughout the State, nearly all of these are readily identified as ichthyosaur or plesiosaur remains (Teichert and Matheson 1944, Long 1990). A specimen which lay unrecognised in the collections of the Western Australian Museum for over 30 years was recently recognised as a partial humerus of a large pterosaur (Bennett and Long 1991), this being Australia's largest known pterosaur, and from Australia's youngest known Mesozoic vertebrate fauna.

Further discoveries of dinosaur footprints in the Broome area by local naturalist Mr. Paul Foulkes have recently been examined by the author, and these extend the known fauna of dinosaurs from Western Australia to include theropods, sauropods, ornithopods, and possibly stegosaurs (Long 1990). In this paper two more bones are described which are believed to be from dinosaurs, despite poor preservation, thus representing the first record of dinosaur bones from the western half of the Australian continent.

Institutional prefixes to catalogue numbers are as follows: Western Australian Museum, WAM; University of Western Australia, UWA.

A LATE CRETACEOUS THEROPOD HUMERUS

The theropod humerus (WAM 90.10.2) was discovered by Mr. George Kendrick, of the Western Australian Museum, from a gully near West Tank, Giralia Station (Fig. 1) in August 1990. The specimen (Fig. 2) shows typical preservation of bone from the late Cretaceous Miria Formation, and there is no evidence to the contrary that the bone had not been derived from that unit. Many fossils such as ammonites, molluscs and shark teeth weather out of the soft sediments of the Miria Formation and are found littering the gullies of the region.

The Miria Formation represents a lag deposit which contains phosphate nodules (Henderson and McNamara 1985). It is richly fossiliferous, containing many forms of ammonites, gastropods, bivalves, rare echinoderms, shark teeth and reptile bones, including those of mosasaurs. The only other outcropping sedimentary units in the area are white chalks of the Wadera Calcarenite (also Upper Cretaceous) and the Palaeocene Boongerooda Greensand. The Wadera Calcarenite represents deeper water, and quiet sedimentation, and to date has not yielded any vertebrate remains, so derivation from that unit is unlikely. The identification of the specimen as most likely belonging to a dinosaur also supports its derivation from the Miria Formation.

The specimen (Fig. 2) shows a slender shaft with an expanded articular end. As preserved, the specimen is 21 cm long, the shaft measures 3.4 cm by 2.6 cm at its smallest cross-section, and clearly shows that the bone was hollow, having a bone thickness of 5.5 mm. The slender proportions of the shaft, and its hollowness, precludes its identification as either ichthyosaur, plesiosaur, mosasaur or chelonian, all of which tend to have robust, stocky limb elements (Romer 1956, Carroll 1988), and lack hollow cavities inside limb bones. The ratio of bone diameter to its wall thickness in a wide variety of vertebrates has been studied by Oxnard (1992). In agile cursorial animals, the ratio is as high as 7, ranging down to 4 in large graviportal animals like elephants. Pterosaurs, birds and bats have high ratios (14-45), whereas aquatic animals tend to lack hollow cavities in bones. The Miria bone has a mean ratio of 5.5 (average diameter), placing it in the main category for terrestrial agile animals, thus supporting the identification of the bone as being that of a dinosaur.

The expanded end of the bone shows a well-developed flange which is damaged, but if reconstructed would probably taper out to form a broad flat area for muscle attachments. This bone has been compared with many types of reptile limb elements and most closely matches that of the humerus in theropod dinosaurs. The broad muscle attachment surface represents the deltopectoral crest which is well-developed in bipedal dinosaurs, and especially so in the theropods (Ostrom 1969, Madsen 1976, Harrison and Walker 1973, Molnar *et al.* 1990). Bipedal ornithopods tend to have stockier, robust humeri because the forearm is generally used to take the weight of the animal when on all fours (e.g. *Muttaburrasaurus* Bartholomai and Molnar, 1981; *Camptosaurus* Marsh (Galton and Powell 1980). Large carnosaurs tend to have more robust humeri with thicker shafts (Molnar *et al.* 1990). The bone may superficially resemble that of a partial sauropod ischium (e.g. *Camarasaurus* Cope; see Cope, Osborn and Mook, 1921: Figs 96-100) but differs in lacking a prominent ischial surface or ridge on the shaft, in not being solid bone, and in the more robust development of the head (or iliac border in ischia).

The combination of having a slender, gracile shaft with a greatly expanded humeral head is restricted amongst large Mesozoic vertebrates to certain families of theropod dinosaurs: coelurosaurs, some ceratosaurs (e.g. *Liliensternus* Welles, ornithomimosaurs, oviraptorids and dromaeosaurs. From biogeographic data it is clear that some dinosaur groups which first evolved late in the Cretaceous and were restricted to North America and Asia (such as hadrosaurs and ceratopsians) would not be expected to occur in Australia, due to the splitting up of landbridges as Gondwana rifted apart. Therefore, we may exclude the presence of oviraptorids, ornithomimosaurs and dromaeosaurids from Australia, but expect the presence of those groups which had evolved by the end of the Jurassic and had opportunity to disperse to Gondwana. These include coelurosaurs (e.g. *Kakuru* Molnar and Pledge 1980; *Skartopus*, Thulborn and Wade 1984) and carnosaurs (e.g. *Allosaurus* Marsh, Molnar *et al.* 1981, 1985; Welles 1983; Long 1990). Abelisaurids, once thought to be endemic to Gondwana, are also known from Europe (LeLoeuff, 1991), and their presence in Australia is at most tentative, based on one metacarpal bone of *Rapator ornitholestoides* Von Huene (Molnar 1991). The humerus of the abelisaur *Carnotaurus sastrei* Bonaparte is somewhat stocky and robust (Bonaparte *et al.* 1990: Fig.28), quite unlike WAM 90.10.2.

Fig. 1. Locality map showing occurrences of dinosaur remains or traces in Western Australia.

Figure 3 shows a comparison between WAM 90.10.2 and the humerus of *Deinonychus antirrhopus* Ostrom, an Early Cretaceous dromaeosaur from North America. The W.A. bone matches closely the shape of the proximal portion of the humerus as far as reconstruction permits. It is clear that the proximolateral flange would correspond to an area of attachment for deltoid and humeroradialis muscles, and the distal projection of that flange of bone would be

Fig. 2. WAM. 90.10.2., proximal half of left humerus of a theropod dinosaur from the Late Maastrichtian Miria Formation, Western Australia. **A**, anterior view. **B**, lateral view. **C**, dorsal view. Bar scale 1cm.

the deltopectoral crest. The head of the humerus is partially preserved, but can be confidently restored from the specimen. It shows the supporting buttress of a robust caput humeri, angled in mesially from the long axis of the shaft. An internal tuberosity was probably developed, as seen on the outline of the bone, and an attachment area for scapulo-humeralis muscles is also clearly defined. In proximal view, the head of WAM 90.10.2, as much as is preserved, has a moderate curvature not as pronounced as the Z-shaped proximal head of the humerus in *Deinonychus* (Harrison and Walker 1973: Fig. 6).

If the bone was reconstructed with similar proportions as the dromaeosaur *Deinonychus*, it would have an estimated total length of about 32-35 cm. As theropod dinosaurs exhibit a great range of forearm sizes, from small dinosaurs with large arms (e.g. *Deinonychus*) to gigantic forms with tiny arms (e.g. *Tyrannosaurus* Osborn), it is difficult to estimate the size of the Western Australian theropod without more tangible anatomical features to narrow down its identification.

In summary, the Western Australian bone most likely comes from a theropod dinosaur

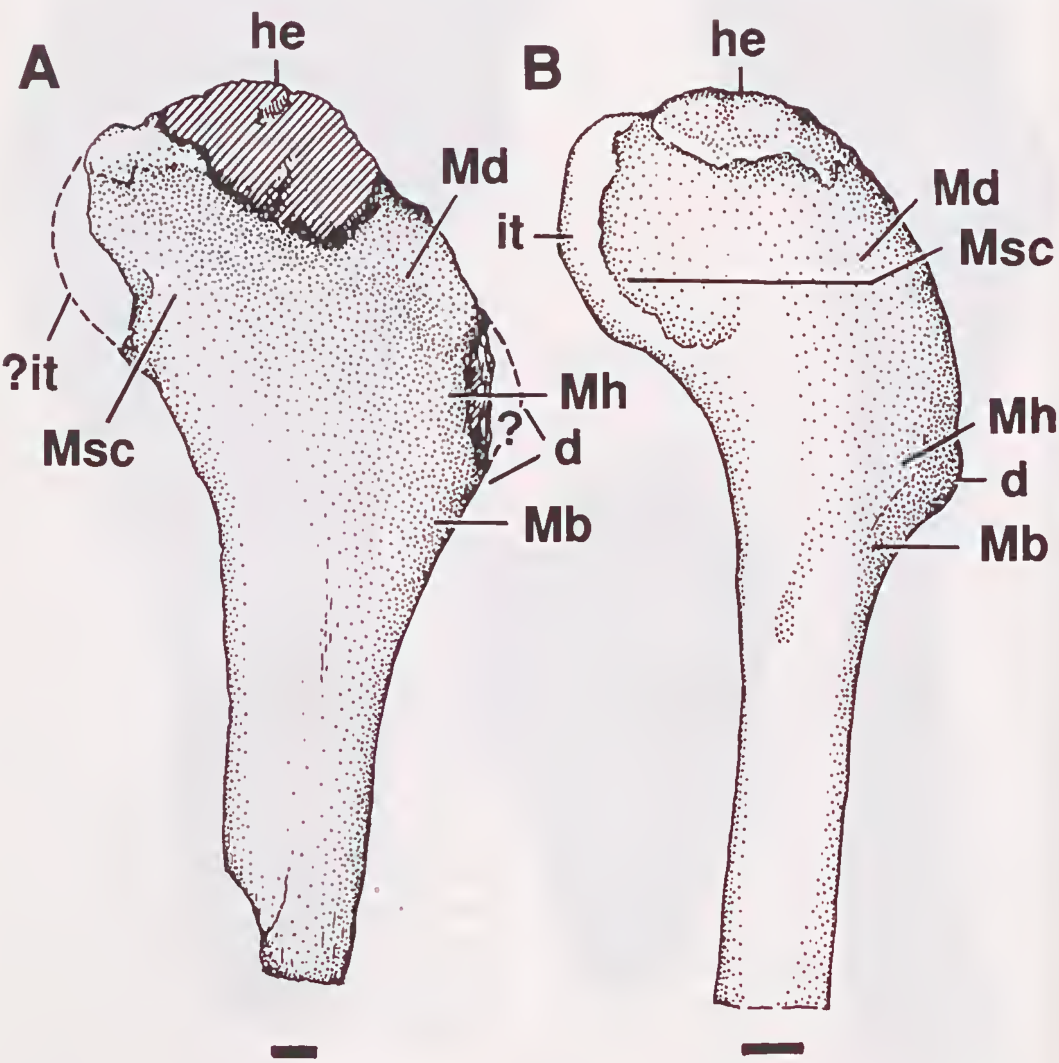

Fig. 3. Comparison between **A**, WAM 90.10.2 and **B**, left proximal part of left humerus from the dromaeosaur *Deinonychus antirrhopus* (after Ostrom 1969). Abbreviations: **d**, deltopectoral crest; **he**, head of humerus; **it**, internal tuberosity; **Mb**, attachment surface for brachialis muscle; **Md**, attachment surface for deltoid muscle; **Mh**, attachment surface for humeroradialis muscle; **Msc**, attachment surface for scapulohumeralis muscle. Bar scale 1cm.

aving slender forearms, possibly one of the rger coelurosaurs. The presence of large rnosaurs and coelurosaurs in the Early Cretaous of Western Australia is known from footints in the Broome area. Although coelurosaurs came extinct by the end of the Early Cretaous in North America, it would not be unusual r the group to have survived later in Australia, other Australian dinosaurs, like *Allosaurus*, ıve been shown to persist to later times when ɔmpared with their relatives in the northern emisphere.

A MIDDLE JURASSIC SAUROPOD VERTEBRA?

A small vertebra from the Middle Jurassic Bajocian) Colalura Sandstone was found at Bringo Railway Cutting, about 20km east of Geraldton, by students from the Geology Department of the University of Western Australia, back in the mid 1970s. The specimen (UWA 82468) was labelled in the collections as a possible plesiosaur vertebra. Several well-preserved vertebrae of plesiosaurs have been found from that unit (Long 1990, p. 53).

The specimen (Figs. 4, 5) is a distal caudal vertebra measuring 6.3 cm in length, 4.7 cm wide, with centrum height of 4.3cm. It is almost complete, missing only part of the anterior central surface and the top of the neural arch. Both of the central surfaces are strongly concave, and the posterior surface has a well-developed posteroventral surface for chevron bone articulation. The neural arch encloses a canal 1 cm in breadth, (1.96 cm total breadth of neural arch) and the neural arch arises 1.9 cm from the

Fig. 4. ?Sauropod caudal vertebra from the Middle Jurassic Colalura Sandstone of Western Australia, UWA 82468. A, right lateral view; **B**, dorsal view (anterior towards top); **C**, posterior view. Natural size.

anterior of the bone where it continues to its posterior extent, broadening posteriorly (neural arch 2.88 cm wide). In lateral view, the bone shows strongly concave ventral margins, and in dorsal view the lateral margins are also strongly concave. Small nutritive foramina are visible on the ventral and lateral surfaces of the bone, but these are not regularly placed nor as proportionately large as those seen in plesiosaur vertebrae.

The bone has been shown to a number of fossil reptile experts and, using the literature, compared with numerous reptile vertebrae from a diverse range of taxonomic groups. Although essentially lacking synapomorphic features which could unite it with certain groups of dinosaurs, it can only be generally said that it closely resembles the distal caudal vertebrae of sauropods. A caudal vertebra of *Austrosaurus* Longman sp. (QM F 7292) was borrowed from the Queensland Museum for comparison. Both show similar general proportions: spindle shape, strongly concave central surfaces; chevron facets on the presumed posteroventral margins, similar development of neural arch shape (basal attachments only). A distal caudal vertebra of *Austrosaurus* sp. from Queensland figured by Coombs and Molnar (1981: Plate 1,S) is also very similar in the relative shape and placement of the neural arch on the vertebral centrum. There is nothing to preclude the Western Australian specimen from belonging to another group of dinosaurs, although lack of representative material in Australia has prevented more extensive comparisons from being made. At this stage it is tentatively identified as dinosaurian, cf. sauropod.

The significance of the specimen lies in that if it is a dinosaur it represents only the second known Jurassic occurrence of skeletal material of dinosaurs in Australia, the other being the sauropod *Rhoetosaurus brownei* Longman, discovered in the 1920s near Roma, Queensland (Longman 1926,1927). The potential for more discoveries of dinosaurs in the Geraldton area is not great however, as outcrop of the Colalura Sandstone is not very extensive. To date, the only known vertebrate remains from this unit have all come from the small railway cutting at Bringo.

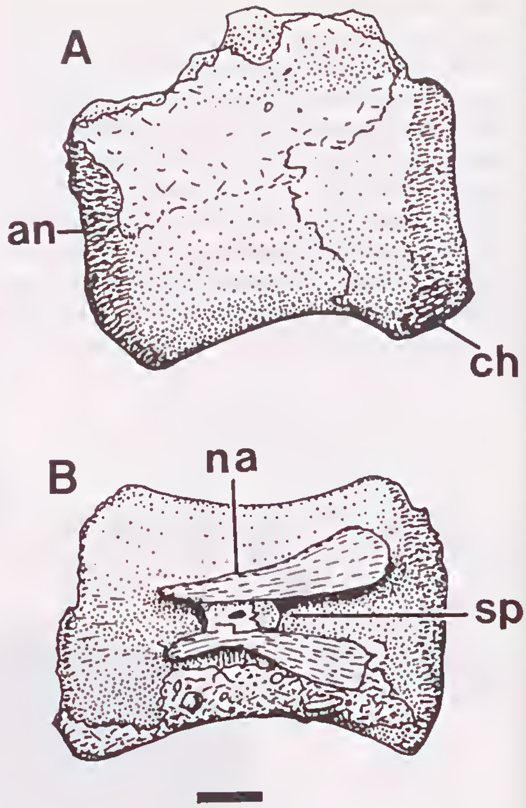

Fig. 5. ?Sauropod caudal vertebra from the Middle Jurassic Colalura Sandstone of Western Australia, UWA 82468. A, left lateral view. B, dorsal view. an, anterior face of centrum; Abbreviations: **ch**, chevron articulation surface; **na**, neural arch; **sp**, cavity for passage of spinal cord. Bar scale 1cm.

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